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Accuracy assessment of the MODIS snow products†

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Abstract:

A suite of Moderate-Resolution Imaging Spectroradiometer (MODIS) snow products at various spatial and temporal resolutions from the Terra satellite has been available since February 2000. Standard products include daily and 8-day composite 500 m resolution swath and tile products (which include fractional snow cover (FSC) and snow albedo), and 0·05° resolution products on a climate-modelling grid (CMG) (which also include FSC). These snow products (from Collection 4 (C4) reprocessing) are mature and most have been validated to varying degrees and are available to order through the National Snow and Ice Data Center. The overall absolute accuracy of the well-studied 500 m resolution swath (MOD10_L2) and daily tile (MOD10A1) products is ~93%, but varies by land-cover type and snow condition. The most frequent errors are due to snow/cloud discrimination problems, however, improvements in the MODIS cloud mask, an input product, have occurred in 'Collection 5' reprocessing. Detection of very thin snow (<1 cm thick) can also be problematic. Validation of MOD10_L2 and MOD10A1 applies to all higher-level products because all the higher-level products are all created from these products. The composited products may have larger errors due, in part, to errors propagated from daily products. Recently, new products have been developed. A fractional snow cover algorithm for the 500 m resolution products was developed, and is part of the C5 daily swath and tile products; a monthly CMG snow product at 0·05° resolution and a daily 0·25° resolution CMG snow product are also now available. Similar, but not identical products are also produced from the MODIS on the Aqua satellite, launched in May 2002, but the accuracy of those products has not yet been assessed in detail. Published in 2007 by John Wiley & Sons, Ltd.

KEY WORDS MODIS; snow covered area; snow products; Terra; Aqua

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INTRODUCTION

Snow may cover up to about 50 million km^2 of the Northern Hemisphere land surface (http://climate.rutgers.edu/snowcover/) and thus has a major impact on the Earth's energy balance because of its high albedo and low thermal conductivity. Albedo, the ratio of reflected to incident solar energy, governs how much solar energy is absorbed by land and ocean surfaces, and can change dramatically, for example from 0·2 to 0·8 or greater, when snow first accumulates. Snow cover also has a major influence on atmospheric circulation by modifying overlying air masses.

Because so much of the water supply used by humans comes from snow cover, especially in mountainous areas throughout the world, snow water equivalent (SWE) is a critical snowpack parameter. However SWE cannot yet be measured remotely with the accuracy required by hydrologic models. To obtain accurate SWE estimates from space, other sources of information, including station data and snow-covered area, should be used, together, to increase their usability in land-surface models.

Moderate-Resolution Imaging Spectroradiometer (MODIS) data, available since 2000, have proven useful for a large variety of land, ocean and atmospheric applications, and a multitude of MODIS standard products is now available. The MODIS standard snow-cover products–providing snow extent and albedo–are useful, or potentially useful, as input to models. The accuracy of these snow products must be known in order to optimize their use.

Two types of validation are addressed in this paper–absolute and relative. To derive absolute validation, the MODIS maps are compared with ground measurements or measurements of snow cover from Landsat data, which are considered to be the 'truth' for this work. Relative validation refers to comparisons with other snow maps, most of which have unknown accuracy. Thus for the studies of relative validation, it is not generally known which snow map has a higher accuracy.

In this paper, we provide the most up-to-date information on the accuracy of each MODIS-derived standard snow cover product in collection 4 (C4 or Version 4 (V004)). C4 refers to the fourth reprocessing of the data-product suite (or the second complete reprocessing). The products have varying degrees of maturity, and because of the different spatial and temporal resolutions, the accuracy is different for different products. Though the focus is on the C4 products derived from the MODIS

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on the Terra satellite, denoted by MOD10, Aqua MODIS products, designated MYD10, are also discussed.

DISCUSSION AND CONCLUSION

Results from various studies show that the daily MODIS snow maps have an overall accuracy of about 93%, but lower accuracy is found in forested areas and complex terrain and when snow is thin and ephemeral. Very high accuracy, up to 99%, may be found in croplands and agricultural areas. Accuracies of the products cannot be stated by providing just one number per product because the accuracy depends on a number of factors such as time of day, season, land cover and topography.

We have discussed both relative and absolute validation. Absolute validation is generally done on the 500 m resolution Terra swath and tile products, MOD10_L2 and MOD10A1, respectively. The products have been validated against 'ground truth' which often consists of meteorological station or SNOTEL data, but also includes field measurements. Relative validation consists of validating the MODIS products against available operational products (e.g. NESDIS and NOHRSC snow products), most of which have *not* been validated though they are being used extensively with good results.

The validation of the Aqua MODIS snow products is not as advanced as that of the Terra products. This is partly because the Aqua products are more recent, and also because researchers are used to using the Terra products and have not yet started using the Aqua products a great deal. The Aqua validation has, thus far, been based on comparisons with the Terra snow products, and while results show good correspondence in most cases, the use of Aqua MODIS band 7 instead of band 6 does produce some differences in the Aqua snow maps relative to the Terra snow maps, and the accuracy of the Aqua snow products appears to be lower because of this, at least in forested areas.

The Terra MODIS snow products have been validated under both ideal and non-ideal conditions, however it is impossible to validate every snow map that is produced. The largest factor affecting the accuracy of the MODIS snow products is snow cloud confusion. Specifically, the cloud mask tends to map more clouds than are really present.

There is a notable improvement in snow mapping in C5 due to improvement in the C5 cloud-mask algorithm. Comparison of the C4 and C5 snow products has revealed many examples of this improvement in boreal regions where typically more snow is mapped in C5 versus C4 products.

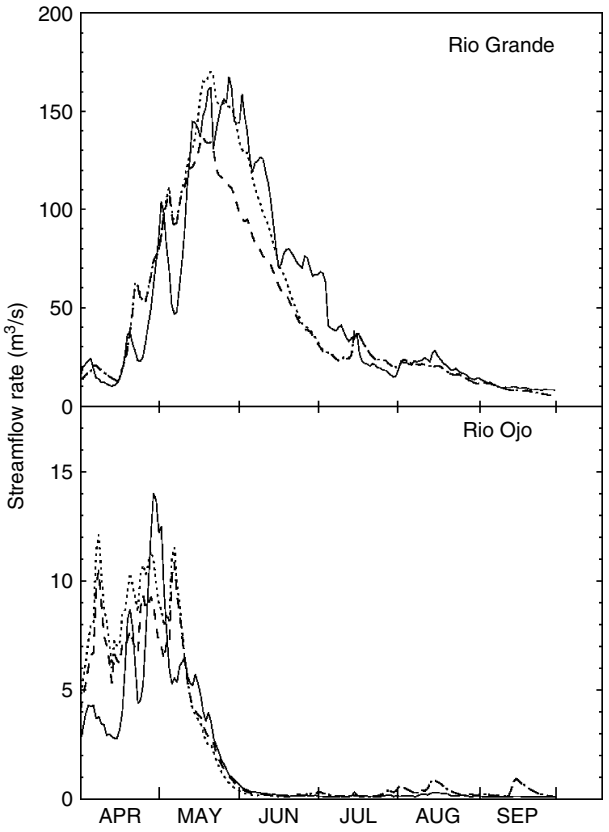

Figure 9. Measured (solid line) and model-simulated streamflow using MODIS- (dotted line) and NOHRSC-derived inputs and the representative parameter values (From Lee *et al.*, 2005)

The MODIS snow cover products compare favourably with operational products and represent improvement in terms of resolution, both spatial and spectral, and also in terms of automated snow mapping and cloud masking. Fractional snow cover in the 500 m resolution products, and the addition of monthly 0·05° and daily 0·25° snow map products are important recent product suite enhancements. The availability of the products at three different spatial resolutions (500 m, 0·05° and 0·25°) makes the products easier for users to utilize and employ in either regional and global studies. The fully automated nature of the MODIS algorithms permits the resultant products to be suitable as candidates for climate data records because of the consistency with which snow cover is mapped globally within a given collection, or reprocessing stream.